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An evolutionary model for GHz Peaked Spectrum Sources Predictions for high frequency surveys

G. De Zotti[1], G.L. Granato[1], L. Silva[2], D. Maino[2], and L. Danese[2]

[1] Osservatorio Astronomico di Padova, Vicolo dell'Osservatorio 5, I-35122 Padova, Italy
[2] SISSA, International School for Advanced Studies, Via Beirut 2-4, I-34014 Trieste, Italy

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Abstract. We have explored, in the general framework of the "young source" scenario, evolutionary models for GHz Peaked Spectrum (GPS) galaxies and quasars which reproduce the observed counts, redshift and peak frequency distributions of currently available samples. Substantially different cosmological evolution properties are found for the two populations: the quasar luminosity function must evolve strongly up to $z \sim 1$, while the data on galaxies may be consistent with no evolution. The models show that GPS sources (mostly quasars) may comprise quite a significant fraction of bright ($S > 1$ Jy) radio sources at $\nu \geq 30$ GHz if the intrinsic distribution of peak frequencies extends up to ~ 1000 GHz. In any case, however, their fraction decreases rapidly with decreasing flux and their contribution to small scale fluctuations in the frequency range covered by the forthcoming space missions MAP and Planck Surveyor is expected to be minor.

Key words: Galaxies: active – quasars: general – Radio continuum: galaxies – cosmic microwave background – Submillimeter

1. Introduction

One of the major uncertainties affecting estimates of microwave fluctuations due to discrete extragalactic sources (Toffolatti et al. 1998; Sokasian et al. 1999; Gawiser et al. 1999) arises from the very poor knowledge of the abundance of radio sources with strongly rising spectra in the frequency range from a few tens to a few hundred GHz, where the most sensitive experiments to map primordial anisotropies of the Cosmic Microwave Background (CMB) are carried out.

GHz Peaked Spectrum (GPS) radio sources [see O'Dea (1998) for a comprehensive review] selected at $\nu \leq 5$ GHz have a fairly flat distribution of peak frequencies, suggesting the existence of an hitherto unknown population of sources peaking at mm wavelengths (O'Dea & Baum 1997; Crawford et al. 1996; Lasenby 1996). Grainge & Edge (1998) report the detection of 50 GPS sources brighter than 50 mJy at 5 GHz and spectra still rising above 10 GHz. The *observed* peak frequency of several of these sources was found to be ≥ 43 GHz; one has a redshift of 3.398 so that the emission peak is above 190 GHz in the rest frame.

It is thus possible that GPS sources significantly contaminate experiments aimed at obtaining very high accuracy (at the μK level), high resolution maps of the CMB, such as those expected from NASA's MAP and ESA's Planck Surveyor missions.

Unfortunately, the very limited information currently available makes it very difficult to carry out reliable predictions of the confusion noise due to these sources. On the other hand, physical models, although still schematic, may provide a useful guide for such predictions. An investigation of this kind may also be useful in connection with the on-going searches of GPS sources peaking at high frequencies (Guerra et al. 1998; Grainge & Edge 1998; Cooray et al. 1998).

Two main scenarios have been proposed to explain the properties of GPS sources. One hypothesis is that their ages are similar to those of classical double radio sources and are kept compact for a large fraction of their lifetimes by interactions with dense gas in their environment (van Breugel et al. 1984; O'Dea et al. 1991; Carvalho 1998). Alternatively, GPS sources may correspond to the early stages of evolution of powerful radio sources (Phillips & Mutel 1982; Carvalho 1985; Fanti et al. 1990, 1995; Readhead et al. 1996a,b; O'Dea & Baum 1997). The latter possibility is currently favoured because the media surrounding radio sources appear to be insufficiently dense to inhibit the radio source growth for a large fraction of its lifetime (Fanti et al. 1995). Also, direct evidences of very short kinematic ages have been found by Owsianik & Conway (1998), Owsianik et al. (1998, 1999) and Stanghellini (private communication).

In this paper we adopt the young, evolving sources scenario. We have elaborated (Sect. 2) on the analytic self-similar evolution model proposed by Begelman (1996, 1999) to account for the main observed population properties of GPS sources (Sect. 3). In Sect. 4 we present pre-

Send offprint requests to: G. De Zotti (dezotti@pd.astro.it)

dictions for counts of GPS sources at MAP and Planck Surveyor frequencies. Our main conclusions are summarized and discussed in Sect. 5.

2. Outline of the adopted evolution model

We make the following assumptions:

1. The initial radio luminosity function (in units of $\mathrm{Mpc}^{-3}\,\mathrm{d}\log {L_i}^{-1}$) is described by a power law:

$$n(L_i) \propto \left(\frac{L_i}{L_\star}\right)^{-\beta}, \quad L_{i,\min} \le L_i \le L_{i,\max}, \tag{1}$$

   where L_i is the luminosity before absorption.
2. In the GPS phase, the properties of the sources are determined by the interaction of a compact, jet-driven, overpressured, non thermal radio lobe with a dense interstellar medium (Begelman 1996, 1999; Bicknell et al. 1997); the timescale of the interaction is very short in comparison with the cosmological-expansion timescale, so that the luminosity evolution of individual sources occurs at constant z. As the radio lobe expands in the surrounding medium, the emitted radio power decreases with the source age, τ, as $L_i \propto \tau^{-\eta}$, and its linear size l increases as $l \propto \tau^{\epsilon}$. If the density of the surrounding medium scales with radius as $\rho_e \propto r^{-n}$, we have (Begelman 1996, 1999) $\eta = (n+4)/[4(5-n)]$ and $\epsilon = 3/(5-n)$. There is a clear anticorrelation between intrinsic turnover frequency, ν_p, and linear size (O'Dea & Baum 1997): $\nu_p \propto l^{-\delta}$, with $\delta \simeq 0.65$. It follows that ν_p scales with time as $\nu_p \propto \tau^{-\lambda}$, with $\lambda = \delta\epsilon$.
3. The spectra of GPS sources are described by:

$$L_\nu = L_p \times \begin{cases} (\nu/\nu_p)^{\alpha_a} & \text{if } \nu < \nu_p \\ (\nu/\nu_p)^{-\alpha} & \text{if } \nu > \nu_p \end{cases} \tag{2}$$

   with $\alpha_a = 0.8$ and $\alpha = 0.75$, the mean values found by Snellen et al. (1998b).

As the radio lobe expands, the peak luminosity L_p varies as the consequence of two factors: the decrease of the emitted radio power and the decrease of ν_p. Hence:

$$L_p(\nu_p) = L_{p,i}\tau^p = L_{p,i}\left(\frac{\nu_p}{\nu_{p,i}}\right)^{-p/\lambda} = L_{p,i}\left(\frac{\nu_p}{\nu_{p,i}}\right)^{\eta/\lambda-\alpha} \tag{3}$$

with $L_{p,i}(z) \propto L_i(z)$ and $p = -\eta + \alpha\lambda$.

If the birth rate of GPS sources is constant on time scales much shorter than the cosmological-expansion timescale, the peak luminosity function per unit $\mathrm{d}\log L_p$ is:

$$n(L_p) \propto L_p^{1/p}. \tag{4}$$

Also, since, in this case, the number of sources of age τ within $\mathrm{d}\tau$ is simply proportional to $\mathrm{d}\tau$ and $\mathrm{d}\tau/\mathrm{d}\nu_p \propto (\nu_p/\nu_{p,i})^{-(1+1/\lambda)}$, the epoch dependent luminosity function at a given frequency ν ($\mathrm{Mpc}^{-3}\,\mathrm{d}\log {L_\nu}^{-1}\,\mathrm{GHz}^{-1}$) writes:

$$n(L_\nu,\nu_p,z) = n_0(1+z)^3 \times \times \left(\frac{L_{p,i}(L_\nu,\nu_p)}{L_\star(z)}\right)^{-\beta}\left(\frac{\nu_p}{\nu_{p,i}}\right)^{-(1+1/\lambda)}, \tag{5}$$

where $L_\star(z)$ is the redshift-dependent normalization luminosity. We have assumed luminosity evolution and adopted a very simple parametrization for it:

$$L_\star(z) = L_0 \times \begin{cases} (1+z)^k & \text{if } z < z_c \\ (1+z_c)^k & \text{if } z > z_c \end{cases} \tag{6}$$

The redshift z_c at which luminosity evolution levels off is a model parameter. We have normalized monochromatic luminosities to $L_0 = 10^{32}\,\mathrm{erg\,s^{-1}\,Hz^{-1}}$.

The luminosity function at a frequency ν_2 is related to that at a frequency ν_1 by:

$$n(L_{\nu_2}) = n(L_{\nu_1}) \times \begin{cases} (\nu_2/\nu_1)^{-\alpha_a} & \text{if } \nu_1 < \nu_2 < \nu_p \\ (\nu_1/\nu_p)^{\alpha_a}(\nu_2/\nu_p)^{\alpha} & \text{if } \nu_1 < \nu_p < \nu_2 \\ (\nu_2/\nu_1)^{\alpha} & \text{if } \nu_p < \nu_1 < \nu_2 \end{cases} \tag{7}$$

The number counts per steradian of GPS sources brighter than S_ν at the frequency ν, with an observed peak frequency $\max(\nu,\nu_{p,\min}) < \nu_{p,0} < \nu_{p,\max}$ are given by

$$N\ (>S_\nu;\nu_{p,0}>\nu) = \int_0^{\min[z_f,z_m(S_\nu)]} \mathrm{d}z\,\frac{\mathrm{d}V}{\mathrm{d}z} \times \times \int_{\max[\nu_{p,\min}(1+z),\nu(1+z)]}^{\min[\nu_{p,\max}(1+z),\nu_{p,i}]} \mathrm{d}\nu_p \times \times \int_{\log L_{\min}(S_\nu,z,\nu_p)}^{\log L_{\max}(z)} \mathrm{d}\log L_\nu\, n(L_\nu,\nu_p,z), \tag{8}$$

where z_f is the redshift of formation of the first GPS sources (we have set $z_f = 3.5$, the maximum observed redshift of a GPS source), z_m is the maximum redshift at which sources can have a flux $\ge S_\nu$, $L_{\min}$ is the minimum luminosity of a source of given z and ν_p yielding a flux $\ge S_\nu$, $\mathrm{d}V/\mathrm{d}z$ is the volume element within a solid angle ω in a Friedman-Robertson-Walker universe ($\Lambda = 0$):

$$\frac{\mathrm{d}V}{\mathrm{d}z} = \frac{c}{H_0}\omega\frac{d_L^2}{(1+z)^6(1+\Omega z)^{1/2}} \tag{9}$$

$$d_L = \frac{c}{H_0}z\left(1 + z\frac{2-\Omega}{2+\Omega z+2(1+\Omega z)^{1/2}}\right) \tag{10}$$

$$S_\nu = \frac{L_\nu K(z)}{4\pi d_L^2} \tag{11}$$

$$K(z) = (1+z)\frac{L_{\nu(1+z)}}{L_\nu}. \tag{12}$$

Similarly, the number counts of GPS sources with an observed peak frequency $\nu_{p,\min} < \nu_{p,0} < \min(\nu, \nu_{p,\max})$ are given by

$$N\ (> S_\nu; \nu_{p,0} < \nu) = \int_0^{\min[z_f, z_m(S_\nu)]} \mathrm{d}z \frac{\mathrm{d}V}{\mathrm{d}z} \times$$
$$\times \int_{\nu_{p,\min}(1+z)}^{\min[\nu\,(1+z), \nu_{p,\max}(1+z), \nu_{p,i}]} \mathrm{d}\nu_p \times$$
$$\times \int_{\log L_{\min}(S_\nu, z, \nu_p)}^{\log L_{\max}(z)} \mathrm{d}\log L_\nu\, n(L_\nu, \nu_p, z)\,, \tag{13}$$

Throughout this paper, we adopt $H_0 = 50\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ and $\Omega = 1$.

The distribution of observed peak frequencies per unit $\mathrm{d}\nu_{p,0}$ in a flux limited sample, $\mathcal{N}(\nu_{p,0}; > S_\nu)$, is given by:

$$\mathcal{N}\ (\nu_{p,0}; > S_\nu) = \int_0^{\min[z_f, z_m(S_\nu, \nu_{p,0})]} \mathrm{d}z \frac{\mathrm{d}V}{\mathrm{d}z} \times$$
$$\times \int_{\log L_{\min}(S_\nu, z, \nu_{p,0}(1+z))}^{\log L_{\max}(z, \nu_{p,0}(1+z))} \mathrm{d}\log L_\nu\, n[L_\nu, z, \nu_{p,0}(1+z)] \tag{14}$$

3. Comparison with observations

3.1. Samples

The available information mostly comes from the samples by Snellen et al. (1998b) and by Stanghellini et al. (1998). Marecki et al. (1999) have recently defined a relatively large sample, but still with a limited fraction of optical identifications and redshifts. A search of GPS sources peaking above 10 GHz has been carried out by A.C. Edge and co-workers; however only a very preliminary report has been published so far (Grainge & Edge 1998).

The sample by Snellen et al. (1998b) comprises 47 sources selected at 325 MHz with a limiting flux density of approximately 18 mJy; it was also required that $S(5\mathrm{GHz}) \geq 20\,\mathrm{mJy}$. Whenever possible, an inverted spectrum between 325 and 609 MHz was used as a criterion to select candidate GPS sources; otherwise, the selection was based on the 325–5000 MHz spectral index. The 325–609 MHz selection yielded 14 sources over an area of 119 square degrees; this is probably a lower limit to the true areal density of GPS sources since the 5 GHz flux limit may introduce a bias against GPS sources with lower peak frequencies and steep spectra beyond the peak. The 325–5000 MHz selection yielded 33 sources over 522 square degrees; the lower areal density, compared with the previous case, although not very statistically significant, may reflect a stronger bias against lower peak frequencies. The condition that spectra of candidate GPS sources can be fitted, within the observed frequency range, by a self-absorbed synchrotron spectrum, discriminates against sources with high values of $\nu_{p,0}$ ($> 8.4\,\mathrm{GHz}$). Snellen et al. (1998a) obtained optical identifications and R and/or I magnitudes for 41 of them. Redshifts were measured by Snellen et al. (1999) for 19 of these. Since GPS galaxies show a tight apparent magnitude-redshift correlation (Snellen et al. 1996), redshift estimates can be derived from photometric data; best fit relationships are provided by Snellen et al. (1996).

Stanghellini et al. (1998) have defined a complete sample of 33 GPS sources brighter than 1 Jy at 5 GHz, over an area of approximately 24600 square degrees. All objects are optically identified and have magnitude estimates; redshifts are available for all but 5 of them. This sample is complementary to that of Snellen et al. (1998b) not only because of the selection at a much higher frequency and at brighter radio fluxes, but also because, with only four exceptions, the peak frequencies of sources are below the frequency of selection, while the opposite is true for the other sample.

The sample by Marecki et al. (1999) comprises 76 sources with 5 GHz fluxes $> 200\,\mathrm{mJy}$ over an area of about 7655 square degrees. The GPS classification, however, may be doubtful for 28 of these sources whose spectral shape is not well determined. As mentioned by the authors themselves, a further uncertainty arises from the variability, typical of flat spectrum sources, which may also lead to a misclassification of some sources as GPS's. Only 21 objects are identified (3 galaxies and 18 quasars) and have measured redshift.

The sample selected by Edge and co-workers is particularly well suited to investigate the abundance of sources peaking at very high frequencies which could be tricky contaminants of CMB anisotropy maps. Grainge & Edge (1998) report the detection of 50 GPS sources brighter than 50 mJy at 5 GHz and peak frequencies above 10 GHz over an area of about 2000 square degrees; they point out that some GPS sources may have been missed because of various selection biasses and, therefore, their result should be regarded as a lower limit. No details on the redshift and peak frequency distributions are given.

3.2. Constraints on model parameters

GPS galaxies and quasars turn out to have different redshift, rest-frame peak frequency, linear size and radio morphology distributions (Stanghellini et al. 1996; Snellen et al. 1998a; Stanghellini et al. 1998). Thus, they must be treated as different populations. Hence, we have fitted separately the redshift and $\nu_{p,0}$ distributions of GPS galaxies and quasars in the samples by Stanghellini et al. (1998) and Snellen et al. (1998b). The counts reported by Grainge & Edge (1998) were used as an additional constraint. The best fit values of the parameters were derived using the routine "amoeba" (Press et al. 1992) exploiting the downhill simplex method in multidimensions.

It became clear quite soon that there is no need for cosmological evolution to account for the observed redshift distributions of GPS galaxies. Therefore, to minimize the number of free parameters, a no-evolution model was

Table 1. Normalization constants and model parameters

	Galaxies	Quasars
L_0 (erg s^{-1} Hz^{-1})	10^{32}	
$\nu_{p,i}$ (GHz)	1000	
z_f	3.5	
n_0 [Mpc^{-3} $(d\log L_\nu)^{-1}$ GHz^{-1}]	5.0×10^{-8}	6.1×10^{-13}
$L_{\rm min}(300\,{\rm MHz})/L_0$	6.7	0.36
$L_{\rm max}(300\,{\rm MHz})/L_0$	2.9×10^5	4.2×10^5
β	0.75	0.59
η	10.7	9.6
λ	8.7	3.9
z_c	–	1
k	–	12.2

adopted [$L_\star(z) = L_0$ in Eq. (5)]. Only very few "local" GPS sources are known; therefore the local luminosity function cannot be determined directly. The power law luminosity function adopted here is fully characterized by four quantities: the normalization n_0, the slope β, the minimum and maximum luminosities. Additional model parameters are η and λ.

Table 1 gives the best fit values of the parameters for both galaxies and quasars. The normalization of the luminosity function and the minimum and maximum luminosities refer to the frequency of 300 MHz.

Figs. 1 and 2 compare the observed peak frequency and redshift distributions of GPS galaxies and quasars in the samples by Stanghellini et al. (1998) and Snellen et al. (1998b), respectively, with those yielded by the model.

Redshifts of the 5 sources (four galaxies and 1 of uncertain identification, assumed to be a galaxy) in the sample by Stanghellini et al. (1998) lacking spectroscopic measurements were estimated using the magnitude-redshift relationships derived by Snellen et al. (1996).

We have assumed that the 19 objects in the sample by Snellen et al. (1998b), identified as star-like by Snellen et al. (1998a), are quasars. As suggested by Snellen et al. (1998a), we have adopted the faint source, rather than the quasar, as the identification of B1647+6225. Of those, 12 have measured redshifts (Snellen et al. 1999); their redshift distribution was taken as representative of the full sample (in practice, the observed number of quasars in each redshift bin was multiplied by 19/12). Only 6 of the 28 "galaxies" have a spectroscopic redshift; for the other alleged galaxies redshift estimates were derived from the magnitude-redshift relationships.

The agreement between model and observed distributions is very satisfactory: the formal value of χ^2 per degree of freedom is $\simeq 1$ both for galaxies and for quasars; a word of caution is in order, however, in view of the many uncertainties following from the various selection effects mentioned in the previous subsection (very difficult to quantify accurately) from photometric redshift estimates (especially for the sample by Snellen et al. 1998b) and from some doubtful identifications.

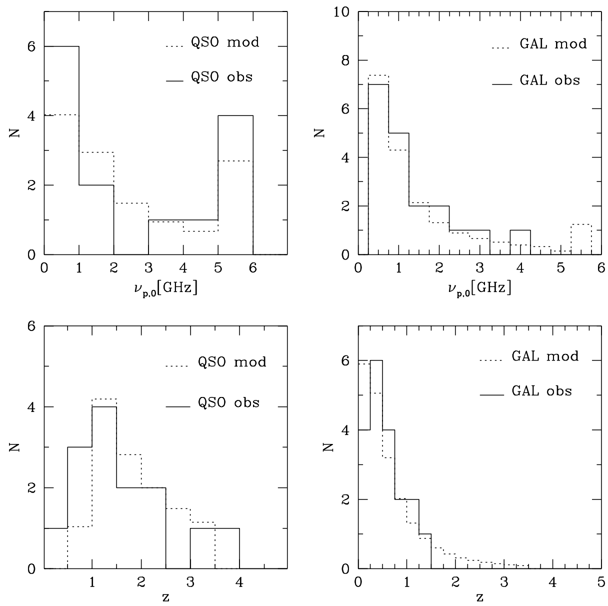

Fig. 1. Peak frequency and redshift distributions of quasars and galaxies in the sample by Stanghellini et al. (1998). The solid lines show the observed distributions. The dotted lines those implied by the model.

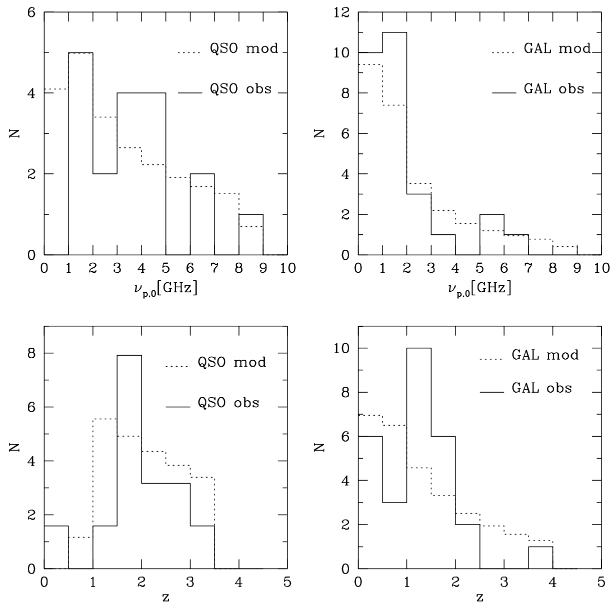

Fig. 2. Peak frequency and redshift distributions of quasars and galaxies in the sample by Snellen et al. (1998b).

The model also yields 56 GPS sources (47 quasars and 9 galaxies) brighter than 50 mJy at 5 GHz and with $\nu_{p,0} > 10$ GHz, over an area of 2000 square degrees, to be compared with a lower limit of 50 sources (no further specifications given) reported by Grainge & Edge (1998).

Assuming that the range of values of ν_0 (0.4 GHz $< \nu_0 <$ 10 GHz) listed in Table 4 of Marecki et al. (1999) corresponds to the range of peak frequencies of GPS sources selected by these authors, the model yields 44 GPS sources (26 galaxies and 18 quasars) satisfying their selection criteria. As mentioned above, although the Marecki et al. (1999) sample comprises 76 sources, only 48 of them have an unambiguous GPS classification.

We stated earlier that no evolution of GPS galaxies is required by the data. On the other hand, the derived evolutionary properties of GPS quasars are quite extreme, although the increase with redshift of the space density at any given luminosity is moderated by the flatness of the local luminosity function and by the relatively low value of the redshift at which the increase stops.

The local luminosity functions of galaxies and quasars have almost identical slopes, significantly flatter than those of conventional radio sources (Dunlop & Peacock 1990). The coincidence of the slopes of local luminosity functions of the two GPS populations may well be fortuitous. In the case of galaxies, the flat slope is required to reproduce redshift distributions extending to $z > 3$ without resorting to cosmological evolution. In the case of quasars, a flat slope may be reminiscent of the effect of relativistic beaming on luminosity functions (Urry & Shafer 1984; Urry & Padovani 1991). Indications that quasar radio flux densities are moderately increased by Doppler boosting (while GPS galaxies are not) are discussed by O'Dea (1998).

An independent estimate of the local luminosity function of GPS sources was recently reported by Snellen & Schilizzi (1999) who also found it to be flatter than that of steep spectrum radio sources. They argue that this is consistent with a scenario whereby GPS sources evolve to Compact Steep Spectrum (CSS) sources and to large-scale double radio sources, provided that the radio luminosity increases with time in the GPS phase and decreases in the subsequent phases.

Since only qualitative arguments are given by Snellen & Schilizzi (1999) it is difficult to analyze quantitatively their model. We may mention, however, that we were unable to obtain a consistent fit to the data sets considered here with parameter values implying an increase of the radio power with increasing age of GPS sources. On the other hand, according to Eqs. (2) and (3), the monochromatic radio luminosity, L_ν, of GPS sources at frequencies $\nu < \nu_p$ varies as $L_\nu \propto \tau^p \nu_p^{-\alpha_a} \propto \tau^{p-\lambda\alpha_a}$. Inserting the values of parameters given in Table 1, it turns out that, in the case of galaxies (but not in the case of quasars), L_ν does *increase* with time ($\propto \tau^{2.8}$).

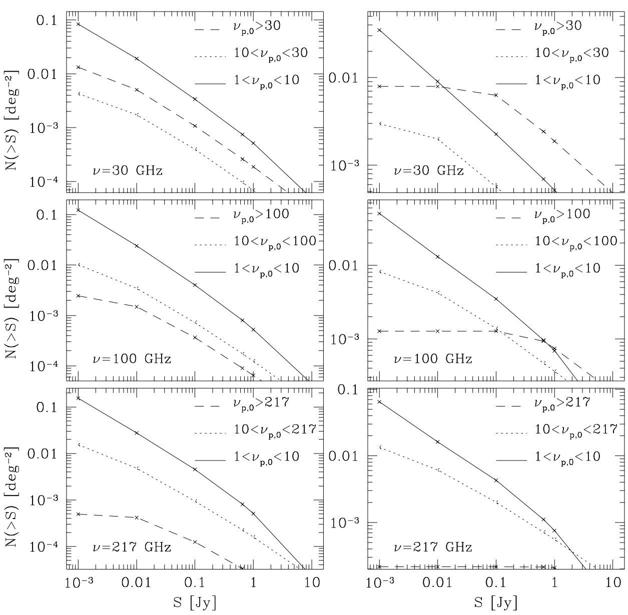

Fig. 3. Predicted counts of GPS galaxies (left-hand column) and quasars (right-hand column) at three Planck Surveyor frequencies for different ranges of observed $\nu_{p,0}$ (GHz) and a maximum intrinsic value $\nu_{p,i} = 1000$ GHz.

The parameters η and λ, characterizing the evolution with the source age of the emitted power and of the turnover frequency, are much larger than expected in the framework of the self-similar evolution model by Begelman (1996, 1999). The physical meaning of this result needs to be further investigated.

4. High frequency counts of GPS sources

The high frequency counts of GPS sources further depend on the maximum value, $\nu_{p,i}$, of the rest-frame peak frequency. We have considered two extreme cases. The results shown in Fig. 3 for three Planck Surveyor frequencies correspond to a very large value, $\nu_{p,i} = 1000$ GHz. On the other hand, since there is direct evidence that values of $\nu_p \geq 190$ GHz do exist (Grainge & Edge 1998), we may take 200 GHz as a lower limit to $\nu_{p,i}$. The corresponding counts are shown in Fig. 4.

The results confirm the rough preliminary estimate by De Zotti et al. (1998): from several tens to a few hundreds of such sources could be detectable by Planck Surveyor instruments.

Not surprisingly, given the high luminosities of GPS sources at low frequencies and their inverted spectra, sources with the highest peak frequencies (mostly quasars, whose peak frequency distribution is weighted towards higher values, as shown by Figs. 1 and 2), show up at the brightest flux levels. If the rest-frame peak frequencies can reach very large values (up to $\simeq 1000$ GHz), high-

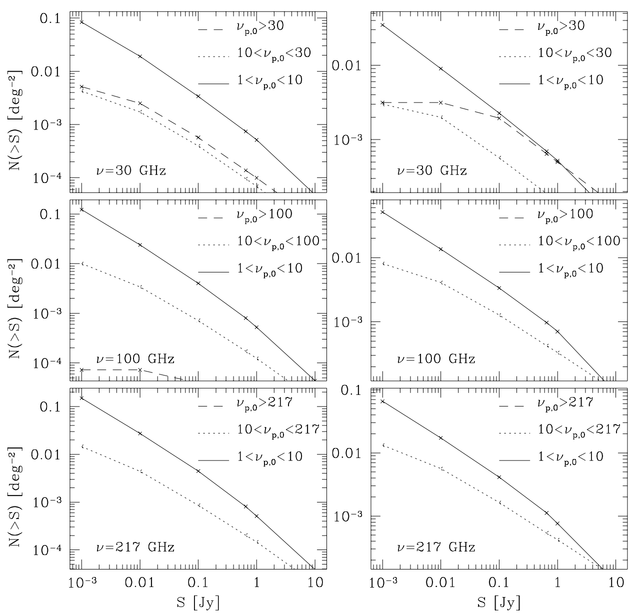

Fig. 4. Predicted counts of GPS galaxies (left-hand column) and quasars (right-hand column) at three Planck Surveyor-frequencies for different ranges of observed $\nu_{p,0}$ (GHz) and a maximum intrinsic value $\nu_{p,i} = 200\,\mathrm{GHz}$.

$\nu_{p,0}$ sources are expected to dominate the bright end of GPS source counts up to $\simeq 100\,\mathrm{GHz}$. A comparison of the results shown in Fig. 3 with the estimates by Toffolatti et al. (1998) and Sokasian et al. (1999) suggests that GPS sources may, in this case, correspond to a substantial fraction (30 to 70%) of bright radio sources ($> 1\,\mathrm{Jy}$) at $\nu > 30\,\mathrm{GHz}$. On the other hand, since their model counts are rather flat, the fraction of GPS sources rapidly decreases with decreasing fluxes; at 0.1 Jy their fraction should drop to $\sim 5\%$, implying that they are a minor contributor to small scale fluctuations due to extragalactic sources.

The areal density of sources peaking at very high frequencies obviously decreases rapidly with decreasing $\nu_{p,i}$. For example, the 30 GHz counts of GPS quasars brighter than 1 Jy with observed $\nu_{p,0} > 30\,\mathrm{GHz}$ decreases by about a factor of 4 as $\nu_{p,i}$ decreases from 1000 to 200 GHz (see Fig. 4), while the corresponding total counts of GPS sources decreases by about a factor of 2.

Given their rather low areal density, only very large area surveys would allow the selection of significant samples of these sources. Planck Surveyor's all sky surveys are unique in this respect.

5. Conclusions

In the general framework of the "young source" scenario we have worked out exploratory models reproducing the observed counts, redshift and peak frequency distributions of currently available samples of GPS galaxies and quasars. The derived values for parameters characterizing the evolution with the source age of the emitted power and of the turnover frequency, however, are substantially larger than those usually quoted. Therefore, the physical interpretation of these results needs to be further investigated.

With the due allowance for the many selection effects and uncertainties related to the identification of bona fide GPS sources, the agreement between model predictions and observational data appears to be satisfactory.

Substantially different evolution properties are required for GPS galaxy and quasar populations, while the derived local luminosity functions of the two populations have a similarly flat slope. This similarity may, however, be fortuitous, particularly if the radio emission of GPS quasars (but not of galaxies) is boosted, and the luminosity function flattened (Urry & Shafer 1984), by a relativistic Doppler effect, as suggested by some observational data (O'Dea 1998).

The model predicts that, if the peak frequency distribution extends to very large values ($\sim 1000\,\mathrm{GHz}$ in the rest frame), GPS sources (mostly quasars) may comprise quite a significant fraction (30 to 70%) of bright ($S > 1\,\mathrm{Jy}$) radio sources at $\nu \geq 30\,\mathrm{GHz}$, according to estimates by Toffolatti et al. (1998) and Sokasian et al. (1999). If the maximum intrinsic peak frequency is $\simeq 200\,\mathrm{GHz}$ [an intrinsic $\nu_p > 190\,\mathrm{GHz}$ has been reported by Grainge & Edge (1998)] the number of GPS quasars brighter than 1 Jy at 30 GHz decreases by about a factor of 4 and the total areal density of GPS sources at the same flux limit decreases by a factor of about 2.

In any case, the counts of GPS sources are expected to be substantially flatter than those of other classes of extragalactic sources. As shown by Figs. 3 and 4, the slopes of integral counts of both galaxies and quasars never exceed 1 and are frequently substantially smaller. This result may be surprising in the case of quasars, given the strong luminosity evolution of their population. One should remember, however, that as z increases, the observational selection picks up higher and higher values of intrinsic peak frequencies and earlier and earlier phases, when the luminosity is higher, of the evolution of individual sources [cf. Eq. (3)]. The duration of early phases, however, rapidly decreases with increasing luminosity; the effect is, in some sense, equivalent to a negative density evolution which compensates for the positive luminosity evolution of the quasar population. This "negative evolution" effect is much weaker in the case of galaxies because their redshift distribution is weighted towards lower values and because the evolution of individual sources is less rapid ($p = -\eta + \alpha\lambda \simeq -4.2$ for galaxies while $p \simeq -6.7$ for quasars).

The flatness of counts obviously implies that the fraction of GPS sources quickly decreases with decreasing flux; as a consequence, their contribution to small scale fluctuations in the frequency range covered by Planck Surveyor and MAP missions is expected to be minor.

In closing, we stress once again the exploratory nature of this study. Several conclusions are still tentative and will need to be reassessed as more data will become available.

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